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Replication of NASPAC Dallas/Fort Worth Study

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16. Abstract

This report describes a simultation study conducted at the Federal Aviation Administration (FAA) Technical Center using the National Airspace System Performance Analysis Capability (NASPAC). The simultation was an attempt to reproduce a study by The MITRE Corporation which examined the effects of the Dallas/Fort Worth (D/FW) Metroplex Plan on NAS delays and throughput. The results of the study closely approximated the results found in the earlier simultation.

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EXECUTIVE SUMMARY

A simulation study of the Dallas/Fort Worth (D/FW) Metroplex Plan was conducted at the Federal Aviation Administration (FAA) Technical Center in April 1990 using the National Airspace System Performance Analysis Capability (NASPAC) model. The purpose of the study was to ensure that the Technical Center version of NASPAC was essentially equivalent to that installed at MITRE, despite minor differences in the operating environment, and to demonstrate the ability of the Technical Center to exercise the model. The simulation was a duplication of a similar effort performed by The MITRE Corporation in August 1989.

The Technical Center study consisted of six scenarios. Input data for these scenarios were provided by The MITRE Corporation. These scenarios included a set of three runs simulating visual meteorological conditions (VMC) at all airports. All modeled airports operated at or near maximum capacity. Another set of scenarios simulated a day representing instrument meteorological conditions (IMC), in which several airport capacities were reduced for varying time periods. Three cases were examined for each weather scenario. Included in the scenario set for each weather configuration was a baseline 1989 condition in which current demand and capacity were represented, a 1995 demand scenario without planned D/FW enhancements, and a 1995 demand scenario with D/FW planned improvements. Results of the MITRE study were compared to the results obtained at the FAA Technical Center for each of these cases.

The comparisons were based on throughput and delay at D/FW and at key airports which serve D/FW. Reductions of technical and effective delay at D/FW as a result of the plan's improvements were also compared.

Results of the two studies were found to be nearly identical. The greatest difference found was 8 percent, with most of the comparisons showing less than 5 percent difference. The differences, for the most part, are attributable to the use of different versions of the preprocessor and simulation model. The Technical Center study clearly supports the results found earlier by MITRE and demonstrates the operability of the NASPAC model at the Technical Center.

INTRODUCTION

BACKGROUND.

In accordance with the Federal Aviation Administration (FAA) Operations Research Office (AOR-100), the ATC Technology Branch (ACD-340) at the FAA Technical Center has been given the task of managing the National Airspace System Performance Analysis Capability (NASPAC) simulation model. NASPAC is an event-step, fast-time simulation of the National Airspace System (NAS). The simulation is broad in scope, in that it attempts to model nearly all essential resources (airports, fixes, sectors) in the entire Continental United States (CONUS). NASPAC is used to forecast the effects of proposed or potential changes to the airspace system on throughput and delay.

The basic components of this model have been transfered to the FAA Technical Center from The MITRE Corporation. In order to ensure the model's integrity as resident on FAA Technical Center's computers and demonstrate the ability of the Technical Center to exercise the NASPAC model, an effort was undertaken to duplicate a previous MITRE study. This report documents the duplication effort by Technical Center personnel of the Dallas-Fort Worth Metroplex Plan Study, performed by The MITRE Corporation in August 1989.

MITRE'S DALLAS/FORT WORTH STUDY.

The Southwest Region of the FAA is engaged in a program of airport capacity and airspace structure enhancements. The program is designed to provide adequate capacity for Dallas/Fort Worth (D/FW) International Airport and its surrounding airspace and satellite airports to meet the expected demand for the next 20 years. These enhancements include additional runways and approach aids, expanded simultaneous Instrument Flight Rules (IFR) approaches, the expansion of the terminal airspace, designing new routes, fixes, and sectors, and expansion of the terminal area. This package of enhancements is known as the D/FW Metroplex Plan.

The FAA and especially the Southwest Region are assessing the impact of the Metroplex Plan on traffic flow at D/FW, the surrounding fixes and airspace, satellite airports, the other key airports that share traffic with D/FW, and on the NAS as a whole. As part of that assessment, The MITRE Corporation conducted a study of the D/FW Metroplex Plan in August 1989, using NASPAC. The analysis was completed, and the final report was issued in March 1990.

MITRE represented those aspects of the D/FW Metroplex Plan in the modeling process which it considered essential and appropriate to the level of detail at which NASPAC operates. Capacity at D/FW was increased in the model to reflect three parallel approach runways. The Metroplex Plan called for the creation of additional sectors and those were generally represented in the simulation. Parallel arrival routes were represented by three arrival fixes at each of the four cornerposts. The parallel arrival streams to D/FW were represented by doubling the capacity of the D/FW stream fix. Additional departure streams were modeled by increasing the capacities of the departure fixes.

The MITRE study included three weather days: a good weather day in which all airports were at or near their maximum capacity, and two bad weather days, in which D/FW and the other key airports operated under instrument meteorological conditions (IMC) for a good part of the day. For each of the three weather conditions, three scenarios were constructed: a 1989 baseline scenario; a 1995 scenario with anticipated traffic increases and improvements at other modeled airports, but not at D/FW; and a 1995 scenario with proposed improvements at all modeled airports, including the D/FW Metroplex Plan.

The MITRE study results showed that the Metroplex Plan as modeled will provide a significant reduction in delays at D/FW, at principal D/FW area fixes, and at key airports that share traffic with D/FW, and will handle the expected growth in traffic.

APPROACH AND METHODOLOGY

OVERVIEW OF THE NASPAC SIMULATION MODEL.

The NASPAC simulation model was developed by The MITRE Corporation for the FAA as an analytic tool for the NAS. NASPAC has been used to simulate the effects of projected demand or capacity changes on system throughput. The model tracks the flight of aircraft through NAS resources including airports, sectors, fixes, and flow restriction areas. Individual events in each flight such as push-back from the departure gate, take-off, crossing sector boundaries and landing and arrival at the destination gate are modeled. Among the system resources represented in the model are 58 airports (50 major and 8 satellite airports in major Traffic Alert and Collision Avoidance System (TCAS), several fixes, and 630 sectors. NASPAC consists of three major processing components: the preprocessor, the simulation model, and the post-processor.

PREPROCESSOR. The preprocessor builds the aircraft flight itineraries which are used to drive the simulation. The preprocessor is comprised of 12 modules and associated command files. These modules process a variety of databases including aircraft schedules, airspace geometry, equipment profiles, and demand and routing information, and produce a single aircraft event file. This aircraft file contains the script for the simulation run, consisting of virtually all the flights during a defined time period (typically 24 hours). Each flight leg record contains the source and destination airports for the flight as well as the sectors, fixes, and restrictions crossed along the way.

At the Technical Center, the preprocessor is resident on a MicroVAX 3900 computer, running under VMS. At the time of the D/FW study, MITRE executed the preprocessor on a VAX 8700.

SIMULATION MODEL. The simulation is an event driven model which traces the progress of all flights within the system during the modeled time period. The simulation program is written in Simscript II.5. Simulations at the Technical Center were executed on a SUN Sparcstation 1, with 12 megabytes of Random Access Memory (RAM). MITRE conducted their study on a SUN 4/370 system with 32 megabytes of RAM.

POST-PROCESSOR. NASPAC post-processing consists of a variety of tools used to generate reports and graphics. Post-processing is performed on SUN and PC systems, using spreadsheets, statistical packages, graphics packages and UNIX utilities. The Technical Center used Freelance to produce the comparative graphs.

MODEL INPUT DATA.

The simulation model uses the estimated capacities of the following Air Traffic Control (ATC) resources: airports, fixes, sectors, and traffic management flow restrictions. Airport capacity is expressed as a range of arrival and departure capacity values. Fix and restriction capacity are expressed in terms of service rates for those resources. These service rates are derived from spacing restrictions between aircraft. For the D/FW study, MITRE turned off the restrictions, except for those associated with the southern california corridor. For sectors, both instantaneous and hourly maximum capacities are input to the model. For the MITRE D/FW study, all existing (and some planned) sectors were modeled, but their capacities were made infinite. Therefore, sector throughput was recorded, but sector delays were not. The same strategy was followed in the Technical Center study. Thirty-four arrival and 47 departure fixes were represented in both studies.

The Official Airline Guide (OAG) is the major source of the demand data. The model also accounts for ground delays issued by Central Flow Control (CFC) because of adverse weather at the destination airport. The Estimated Departure Clearance Times (EDCT) are computed and appended to the schedule for each affected flight. Unscheduled demand is described by daily and hourly distributions taken from real world data. The primary source of the unscheduled demand information is the "Host Z" data collected from Air Route Traffic Control Centers. Forecast of future demand is based on the FAA's Office of Aviation Policy and Plans (APO) Terminal Area Forecasts.

The weather data used by the model is obtained by MITRE via a direct line to the Weather Message Switching Center (WMSC) in Kansas City. The data are used to modify airport capacities and to determine airport runway configuration and mode of operation: visual flight rules (VFR), marginal visual flight rules (MVFR), or instrument flight rules (IFR). The Technical Center duplicated the study by using the input files provided by MITRE along with the same time frame and enhancements in all modeled airports.

The aircraft file is the output of the preprocessor, and the main input to the simulation model. The Technical Center generated an aircraft file independently, but it was constructed using data files supplied by MITRE. Currently, the Technical Center has limited access to the data sources used by MITRE to develop the scenario definitions. The Technical Center will obtain access to these data sources, required for independent operation of NASPAC, by the end of 1990.

SCENARIO DEFINITIONS.

Scenarios are defined by several variables including weather, airspace geometry, time-frame, capacity, and demand. MITRE performed the D/FW study using nine scenarios. The nine scenarios consisted of three different weather conditions (two instrument meteorological conditions (IMC) days and one visual meteorological conditions (VMC) day) for 1989 and for 1995, with and without the D/FW improvements (Table 1). The FAA Technical Center simulated two of the weather days, for a total of six scenarios. Three scenarios were associated with all VMC weather at every airport and the other three represented an IMC day. A 1989 baseline scenario used traffic samples from March 2, 1989, and all VMC weather. A second scenario consisted of VMC weather, and 1995 airspace changes and demand levels, including the planned D/FW improvements. The third VMC scenario included 1995 demand and airspace changes, but without the D/FW improvements. The three other scenarios repeated the conditions of the first three, but with IMC based on the weather of February 14, 1989. On this day, D/FW was under IMC for approximately 17 hours.

MODEL OUTPUT DATA.

The simulation generates delay and throughput statistics. Throughput refers to the number of aircraft using a resource per unit of time. For airports, throughput represents the number of arrivals and departures. Two types of delay are measured.

TABLE 1. SCENARIO MATRIX

	1989	1995 No D/FW Changes	1995 with D/FW Changes
VMC	M, TC	M, TC	M, TC
IMC1	M, TC	M, TC	M, TC
IMC2	M	M	M

Key: M = Mitre
TC = Technical Center

Technical delay corresponds to time spent waiting in a queue for a resource. Some of these queues exist only in the simulation model and not in the real world--such as a queue for an arrival or departure fix. Total technical delay for a flight equals the sum of the individual queueing delays encountered during the flight. Effective delay measures the difference between the scheduled landing time and the actual landing time of an aircraft. Unlike technical delay, effective delay captures delay propagated across flight legs.

The simulation program tallies total system technical and effective delay and calculates average delays per flight. Statistics are also recorded for individual components of the airspace system included in the model. Delays and throughput associated with individual sectors, arrival and departure fixes, and restrictions are reported. The simulation produces a statistical report on individual airport in which effective and technical delays and throughput for each of the 58 modeled airports are given. The simulation will optionally generate a trace report consisting of individual flight histories. Trace reporting was turned off during the simulation runs for this study due to storage space limitations of the current system and because analysis at this level of detail was not required.

For the D/FW study, analyses focused on the same measures detailed in the MITRE study. These include delays and throughput at D/FW and effective delays at key D/FW source/sink airports.

The key D/FW airports were defined as those six having the most traffic with D/FW (excepting Denver Stapleton). The same criterion was used to define the key airports in the present study.

RESULTS

Figure 1 illustrates the comparison of total throughput at D/FW for the VMC day using three different scenarios. These included a 1989 baseline, reflecting current demand and capacity at D/FW, a no improvement scenario at D/FW, representing future demand and current capacity at D/FW, and a planned improvements scenario which represents future demand and capacities at D/FW. As the figure indicates, only minor differences between the two studies exist for total throughput at D/FW. For the IMC day (figure 2) the results were also very close. The largest difference between the two studies on the D/FW total throughput measure was less than 2 percent.

Figures 3 and 4 provide a comparison of total effective delay at D/FW for the two weather scenarios. The VMC day produced a 2 percent difference for the 1989 baseline condition, a 1.8 percent difference for the no D/FW improvements scenario, and a 1 percent difference for the D/FW improvements scenario. For the IMC day, an 8 percent difference was found for the 1989 baseline condition, a 2 percent difference for the no D/FW improvements scenario and less than 1 percent for the D/FW improvements case.

Total technical delay at D/FW is shown in figure 5 for the VMC condition and figure 6 for the IMC day. For the VMC day, the no D/FW improvements scenario yielded a 4 percent difference between the two simulation runs, with the other two scenarios showing smaller differences. The IMC technical delay differences were all in the range of 4-5 percent.

For total system effective delay (figure 7) under VMC, the differences between the studies were under 2 percent. Under IMC conditions (figure 8), the 1989 baselines were nearly identical and the two 1995 scenarios were again in the 4-5 percent range.

Effective arrival delay at major airports is depicted in figures 9 and 10. The largest difference was approximately 7 percent at Pheonix Airport for the IMC 1995 scenario. All other results for the airports shown on the two weather days are within 6 percent.

Total effective delay results for key airports are given in figure 11 for the VMC and figure 12 for the IMC day. Results are shown for the two studies for each airport with and without the planned D/FW improvements. All differences between the MITRE and Technical Center simulations were within 5 percent.

Figures 13 and 14 illustrate the percent reduction in effective and technical delay for the two weather conditions. The largest difference in reduction occurs for technical delay - 8 percent for the VMC day and 7 percent for the IMC day. Results of the two studies for the other types of delay differed by less than 5 percent.

Differences in results between the studies conducted by MITRE and by the Technical Center are primarily attributable to the use of different versions of the preprocessor and the simulation model software. In addition, at the time the MITRE study was conducted, the VAX/VMS SORT utility was invoked without an option which ensures that the order of records with matching keys is preserved. Performing the sort twice on the same data may produce slightly different output each time. Given this nondeterministic factor in the sorting and the differences in preprocessor code, the simulations in the two studies were almost certainly driven by different aircraft event files. This is supported by the minor difference in the number of flights recorded for each scenario (64181 versus 64210 for the 1995 IMC day). The use of different aircraft files will produce perturbations in delay and this would tend to be reflected in the individual airport statistics in particular, where some of the larger differences were found.

There is also a stochastic element in the simulation program. Flight times are generated randomly around a probability distribution. Although both studies used the same random number generator seed, the same seed applied to different sequences of flight profiles produces an additional source of variance.

Another possible explanation for the minor differences in results is that different versions of one or more of the data files were used in the two studies. Despite efforts to ensure that the same data files were used, this possibility cannot be entirely ruled out.

CONCLUSIONS

The replication of the MITRE Dallas Fort/Worth (D/FW) study demonstrates that National Airspace System Performance Analysis Capability (NASPAC) is operational at the Technical Center and may be reliably used in future studies. The simulation also supports the results obtained by MITRE in their D/FW study. Future simulations at the Technical Center will be conducted using independent data sources. During the process of transitioning the model to the Technical Center, NASPAC may again be used to validate and augment previous or ongoing studies.

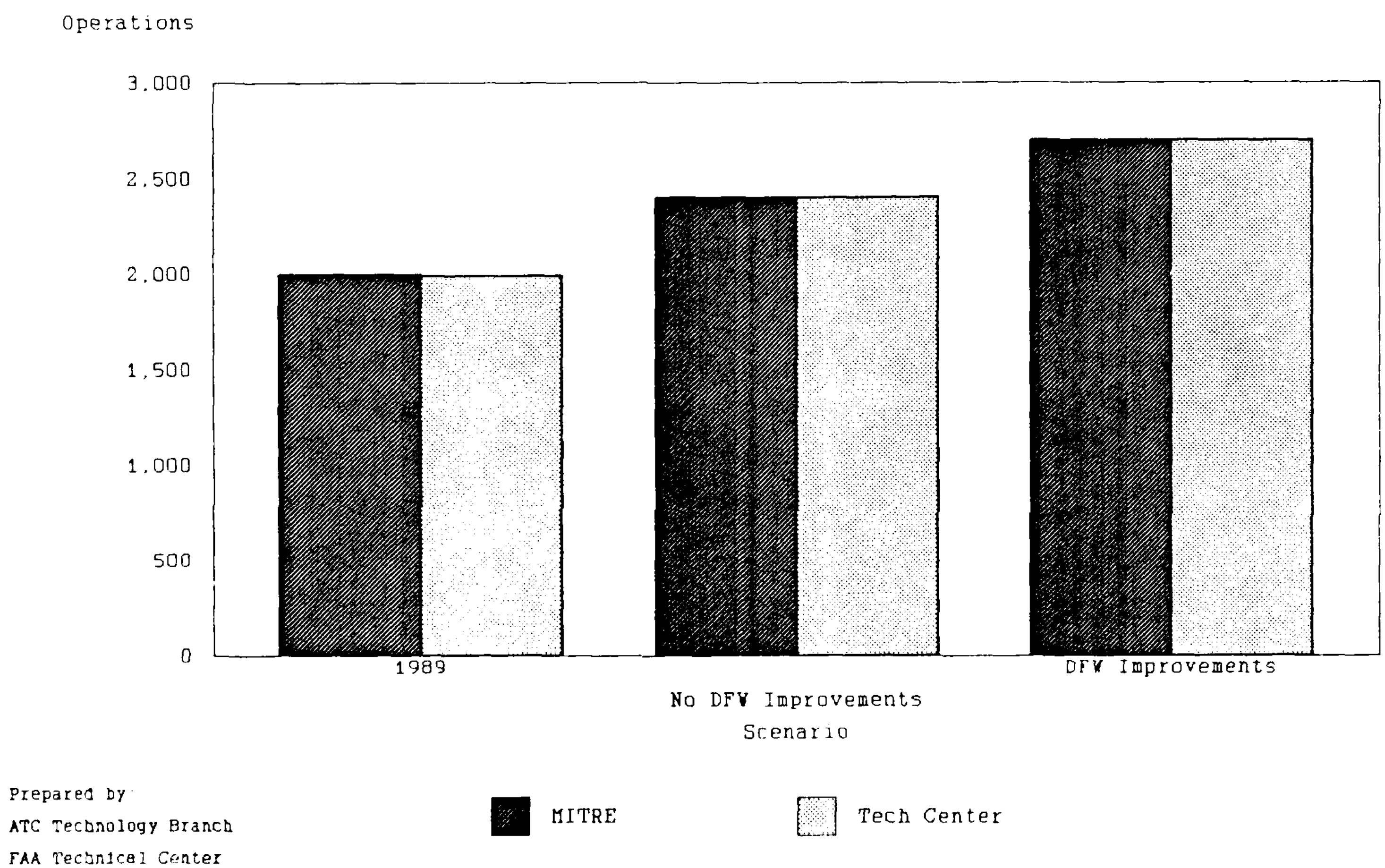

FIGURE 1. TOTAL THROUGHPUT AT DFW FOR VMC DAY

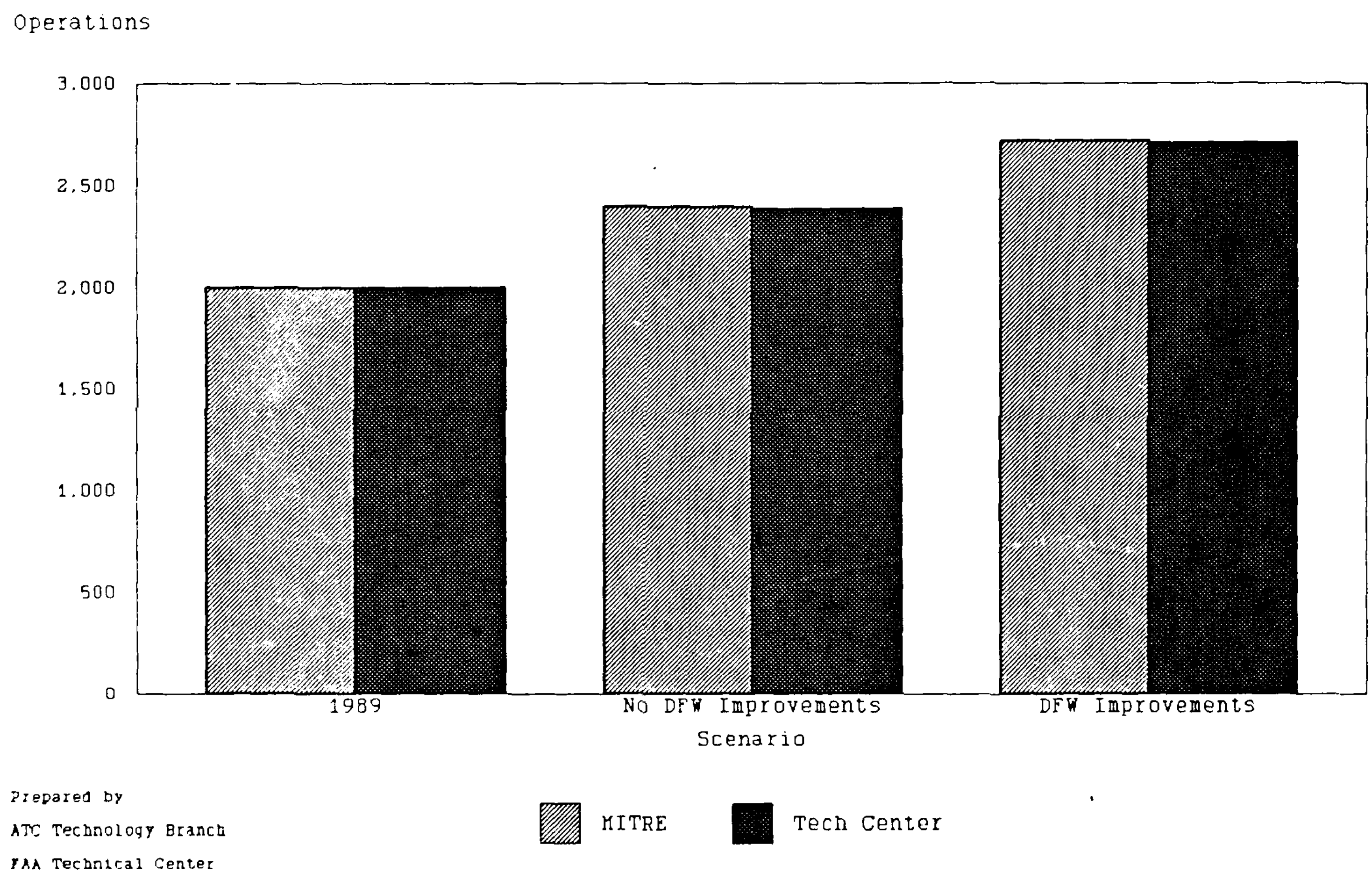

FIGURE 2. TOTAL THOURGHPUT AT DFW FOR IMC DAY

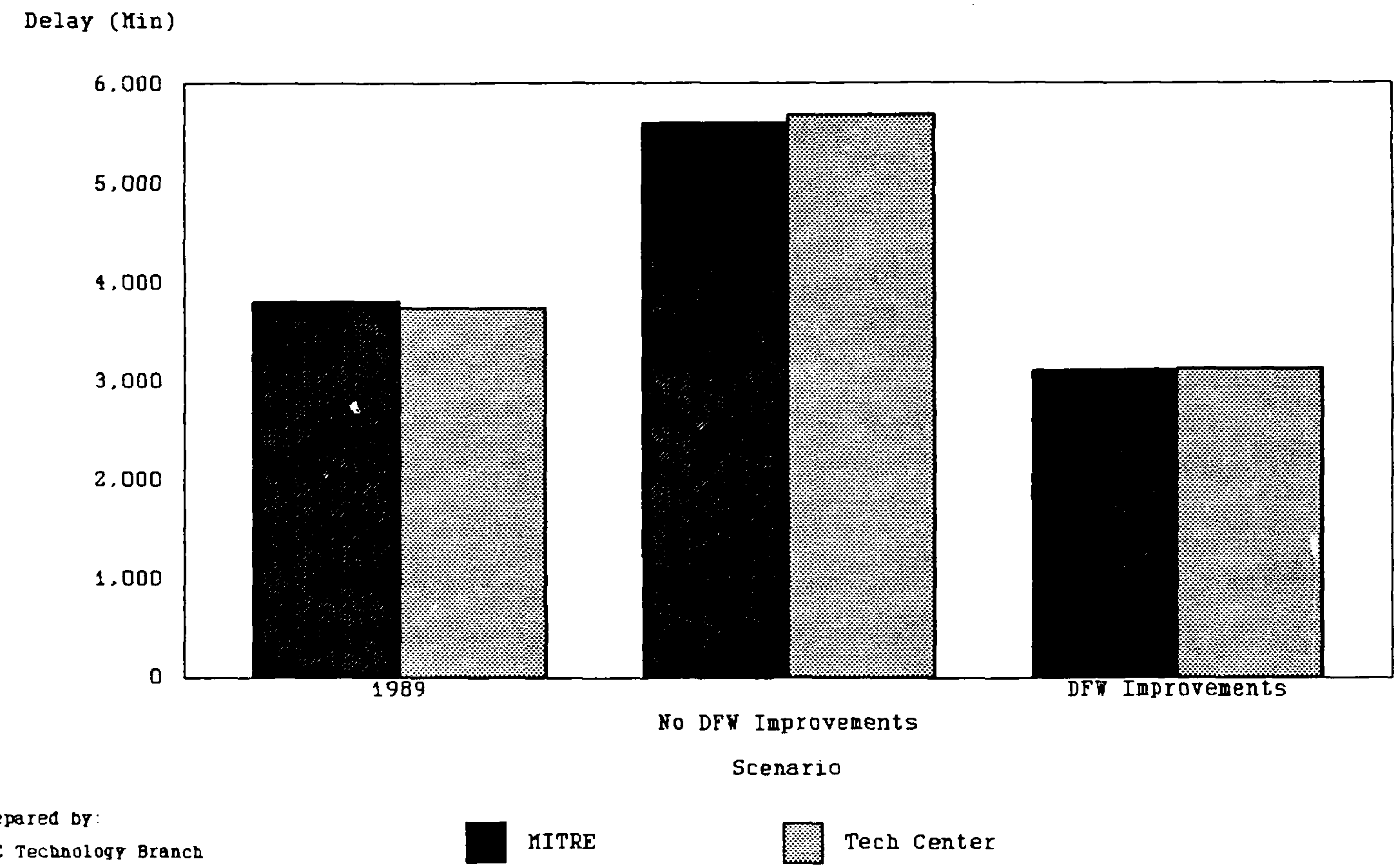

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FIGURE 3. TOTAL EFFECTIVE DELAY AT DFW FOR VMC DAY

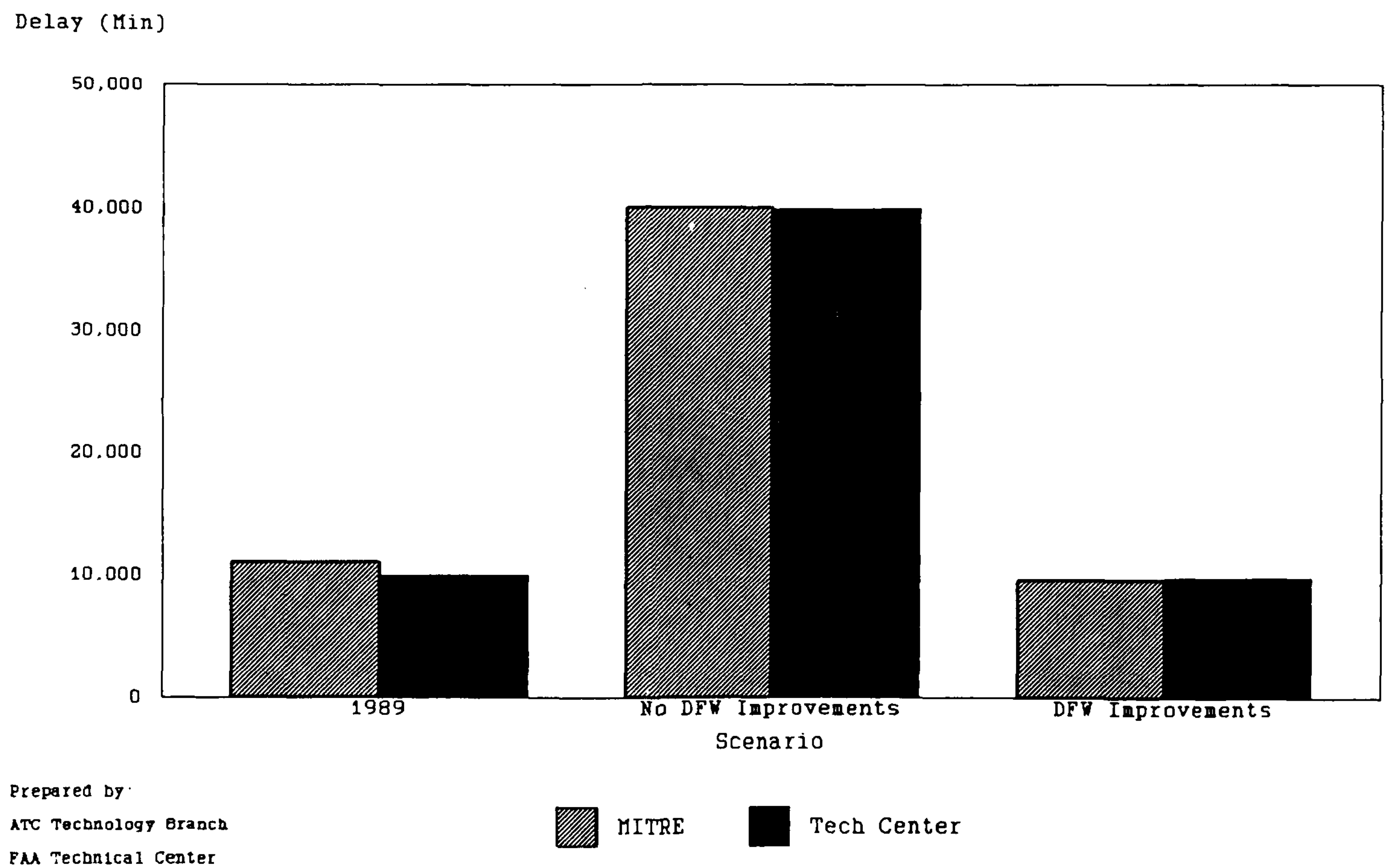

FIGURE 4. TOTAL EFFECTIVE DELAY AT DFW FOR IMC DAY

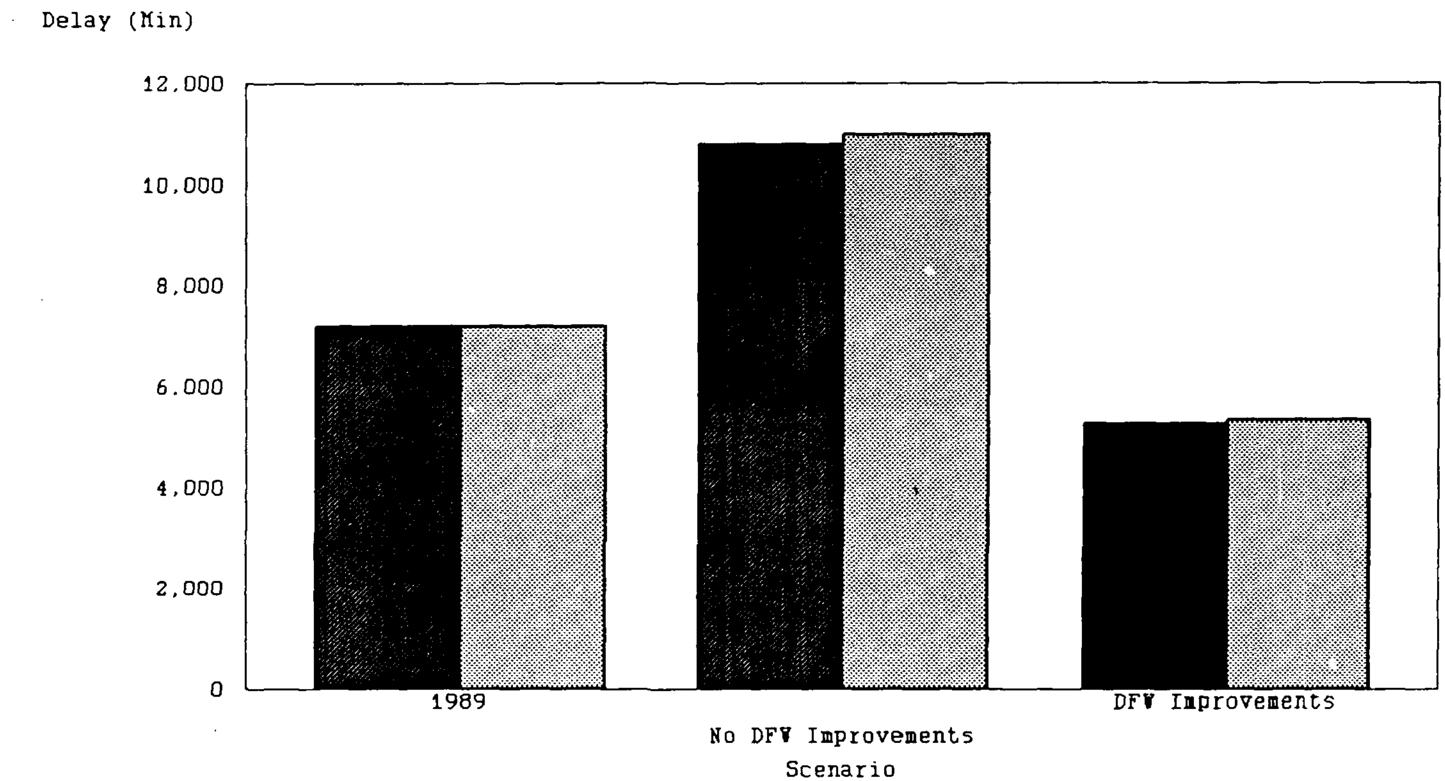

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FIGURE 5. TOTAL TECHNICAL DELAY AT DFW FOR VMC DAY

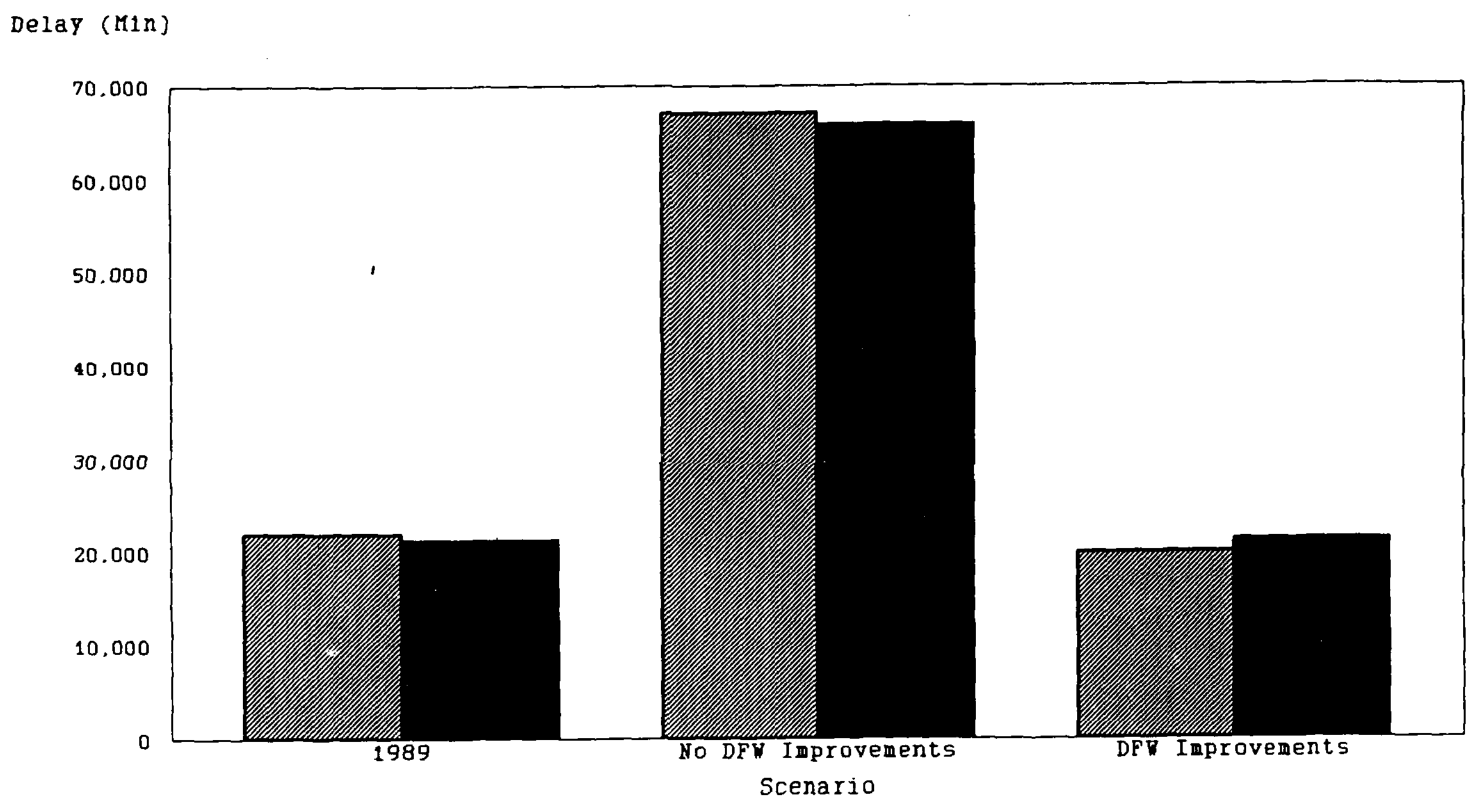

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FIGURE 6. TOTAL TECHNICAL DELAY AT DFW FOR IMC DAY

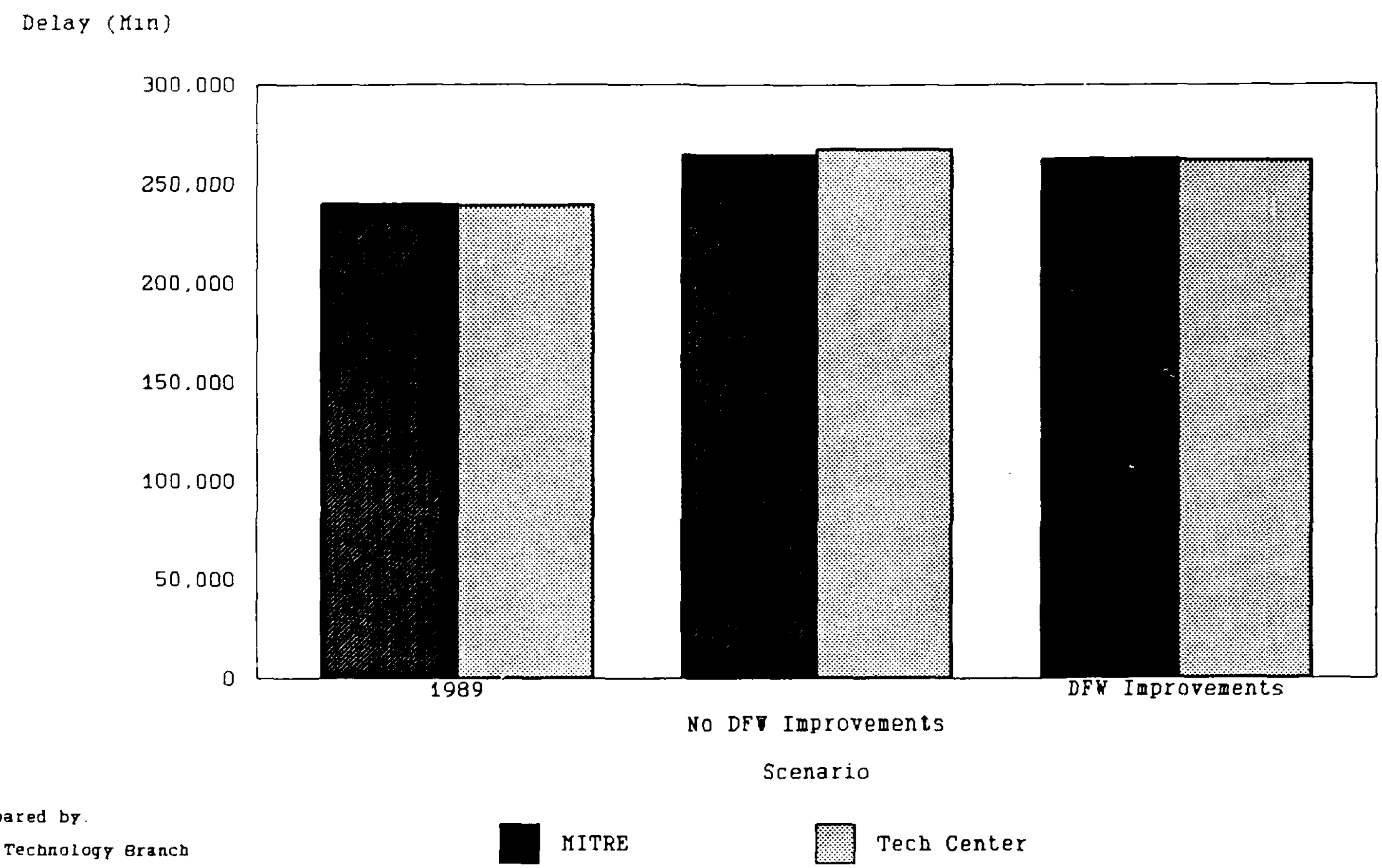

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FIGURE 7. TOTAL SYSTEM EFFECTIVE DELAY FOR VMC DAY

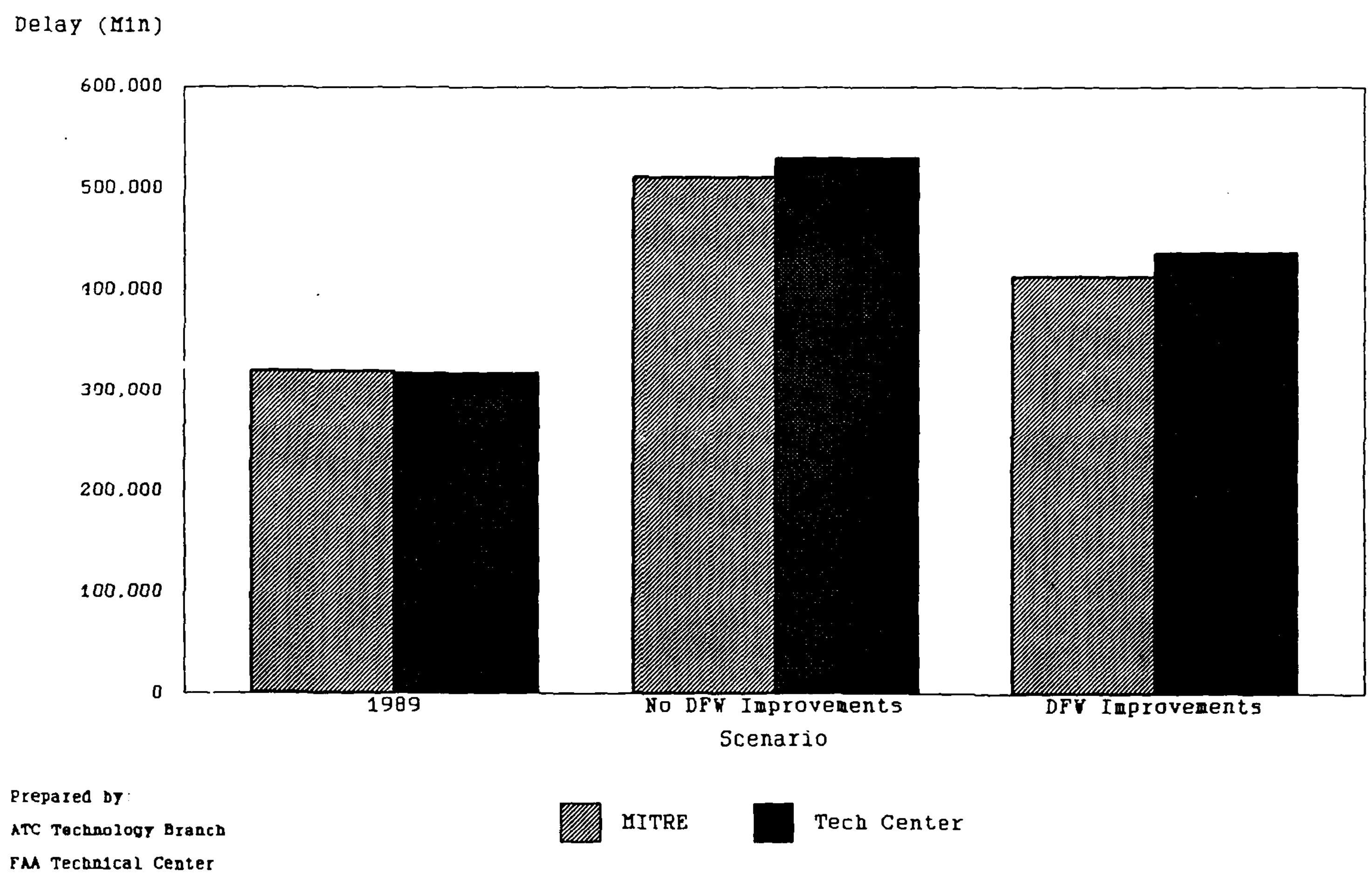

FIGURE 8. TOTAL SYSTEM EFFECTIVE DELAY FOR IMC DAY

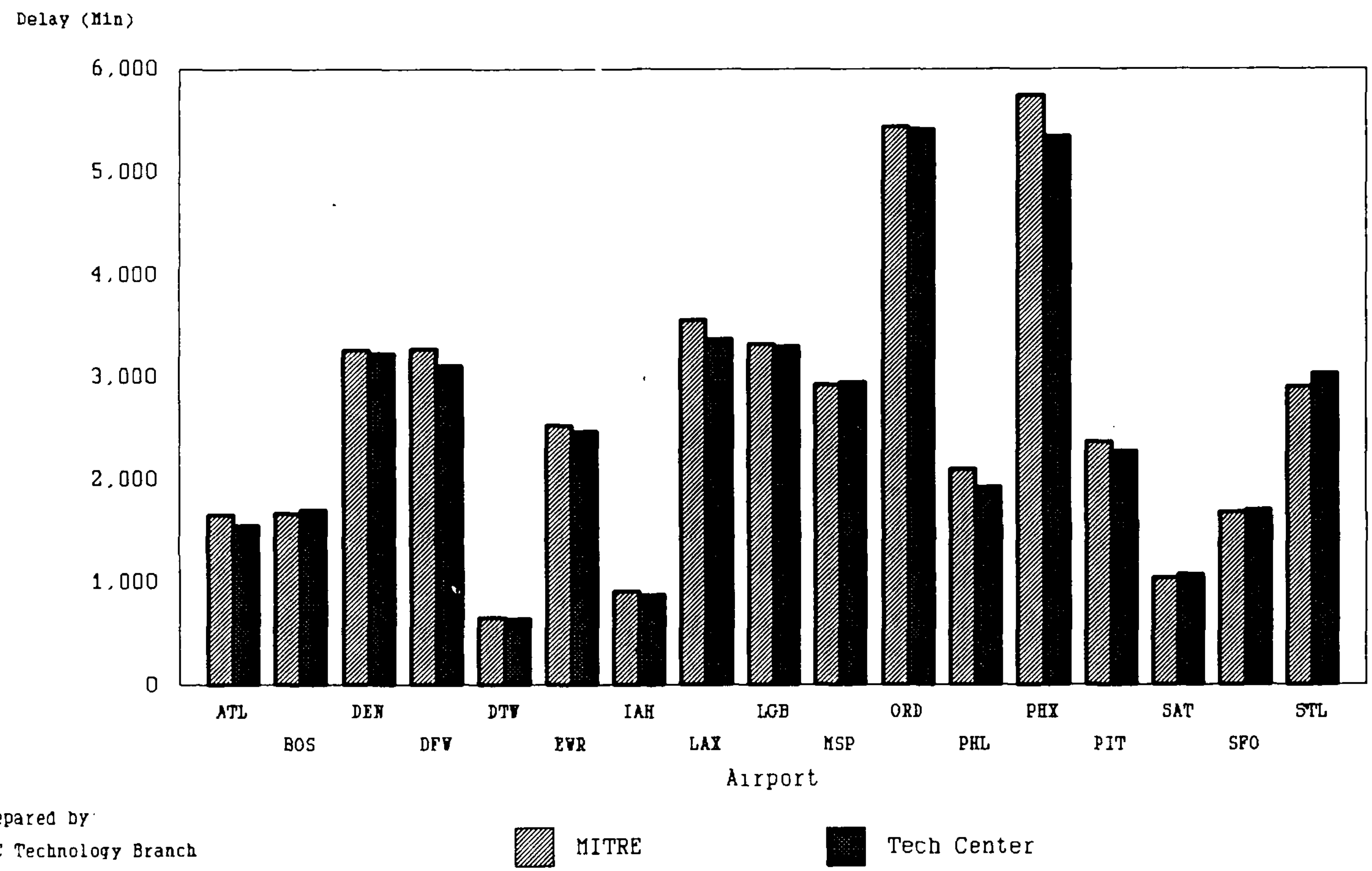

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FIGURE 9. EFFECTIVE ARRIVAL DELAY AT MAJOR AIRPORTS FOR 1995 VMC DAY

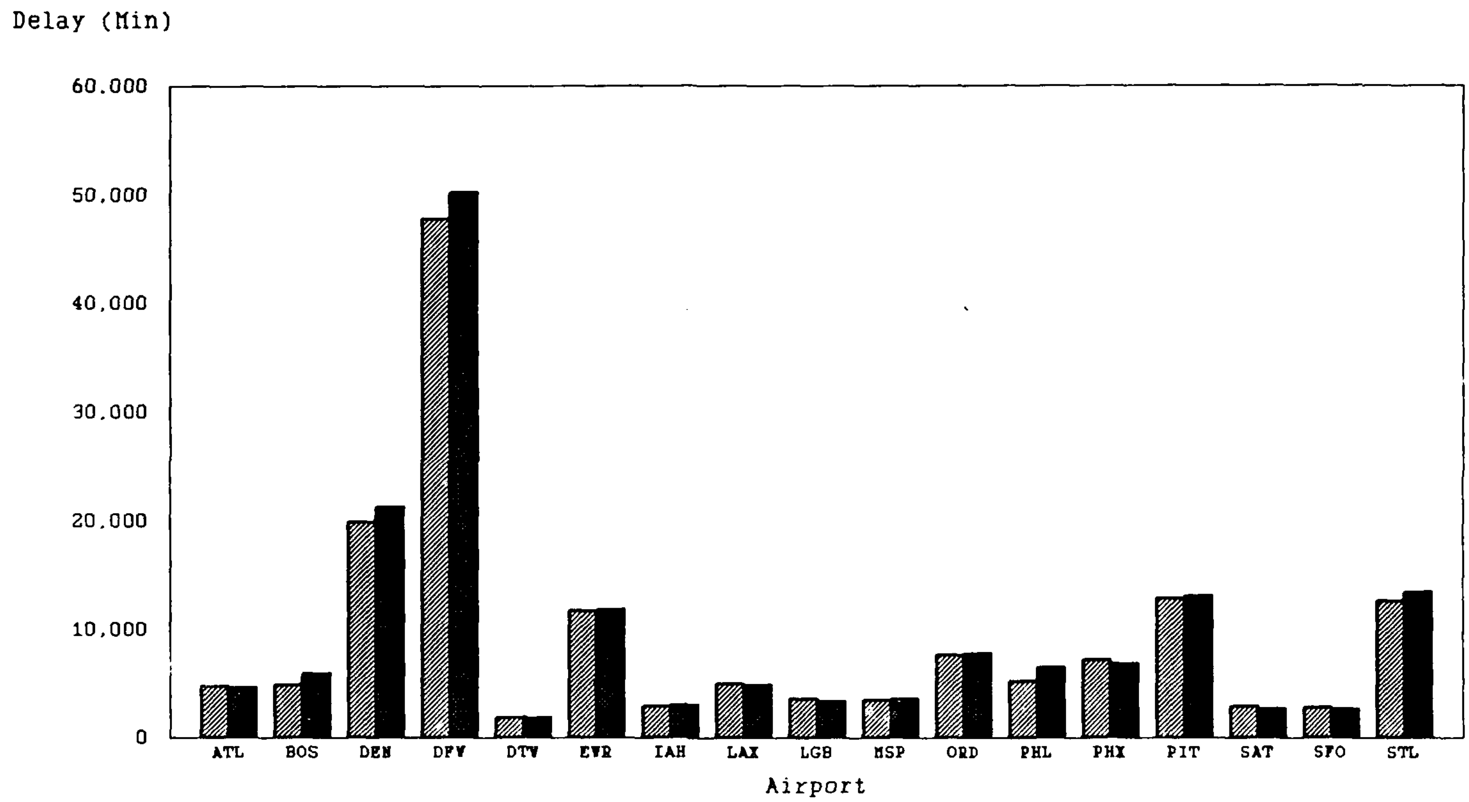

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FIGURE 10. EFFECTIVE ARRIVAL DELAY AT MAJOR AIRPORTS FOR 1995 IMC DAY

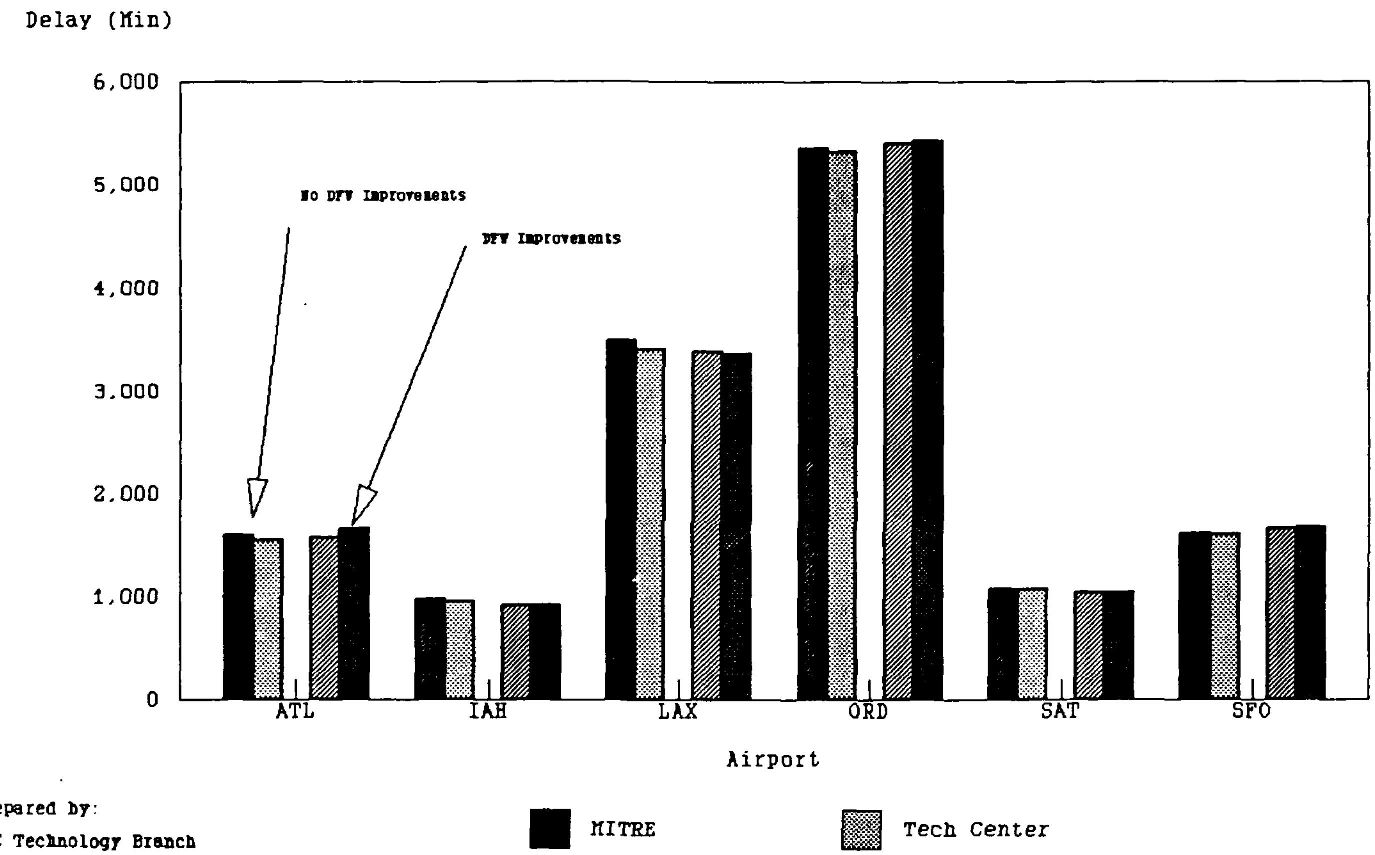

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FIGURE 11. TOTAL EFFECTIVE DELAY AT KEY AIRPORTS FOR 1995 DAY

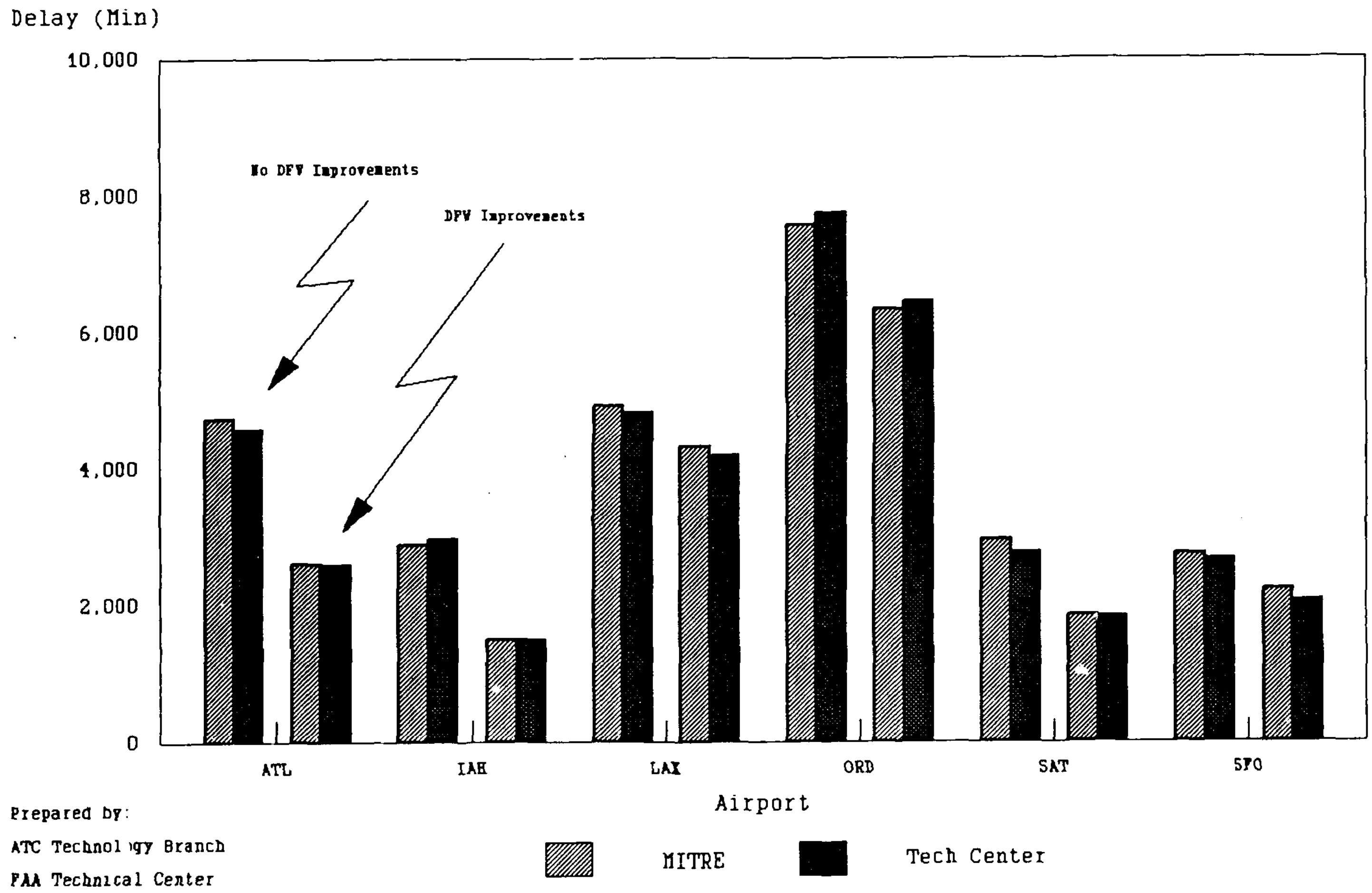

FIGURE 12. TOTAL EFFECTIVE DELAY AT KEY AIRPORTS FOR 1995 IMC DAY

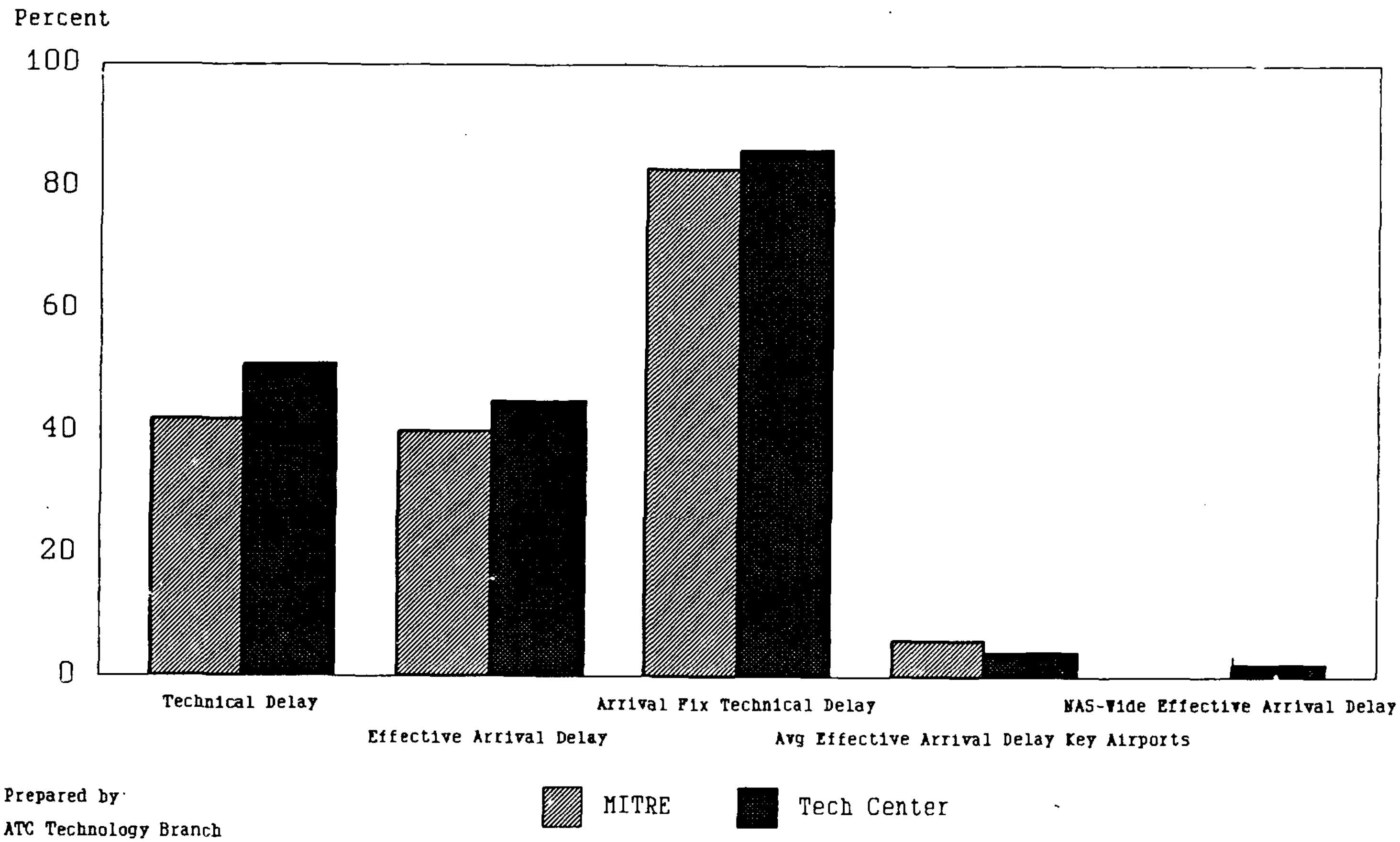

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FIGURE 13. SUMMARY OF STUDY FINDINGS (% REDUCTION) AT DFW FOR VMC DAY

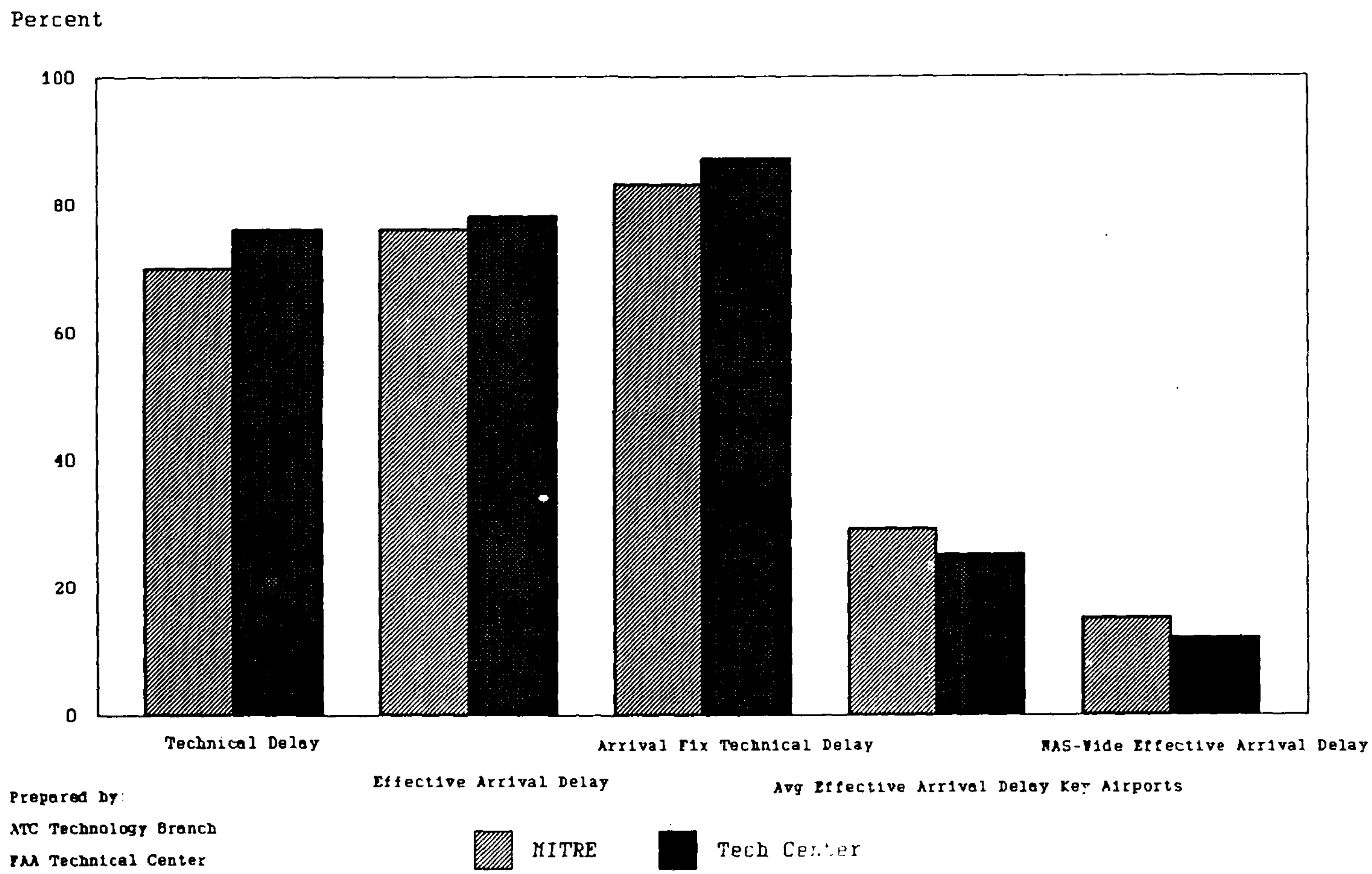

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FIGURE 14. SUMMARY OF STUDY FINDINGS (% REDUCTION) AT DFW FOR IMC DAY

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